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## A Non-traditional Approach to Improving Fleet Supportability

James A. Raley, Veda Incorporated

Donald Nedresky, Naval Air Warfare Center-Aircraft Division

### BACKGROUND

Parts obsolescence in military avionics is inevitable. The typical acquisition program for new military avionics systems requires a minimum of five years from concept exploration to fleet deployment. By the time the new system is deployed in the fleet, it is usually well behind the current state-of-the-art. Often, the threat that the system was designed to counter has been replaced by a different, newer threat for which the system was not designed. It is also possible that the components and processes that were used to develop the system have become obsolete, so that replacement parts are no longer available. In either case, some action must be taken to resolve the obsolescence problem.

Traditionally, the solution to parts obsolescence in military applications is to have the aircraft prime contractor develop an engineering change proposal (ECP) to replace the obsolete equipment with newer, supportable equipment. Unfortunately, the ECP process is costly and time consuming. In addition, the new equipment incorporated by the ECP often reaches the fleet before all logistics support elements are in place. Any gains achieved by incorporating the new equipment are offset by the inability of fleet maintenance personnel to effectively maintain and support it.

The Navy E-2C community was recently faced with a parts obsolescence problem with the ME-252/ASM-33 Digital Volt-ohmmeter (DVOM). The DVOM, which is part of the AN/ASM-440 In-flight Performance Monitor System, is used by operators and maintenance personnel to provide a remote display of radar transmitter power, radar voltage-standing wave ratio (VSWR),

and aircraft line voltage. The DVOM is of an early 1960's design vintage. It uses nixie display tubes, which exhibit poor reliability. Current Navy Maintenance and Material Management System data indicate a Mean Flight Hours Between Failures of approximately 350 hours for the DVOM. More significantly, the DVOM has become logistically insupportable. Manufacturers have ceased production of piece parts and spare shop replaceable assemblies needed to repair the DVOM.

Another drawback associated with the DVOM is its weight. The E-2C is approaching its maximum catapult weight when presently planned upgrades are considered. The DVOM weighs 28 pounds, which is excessive for a device that is used to simply display radar power, VSWR, and aircraft line voltage. The DVOM also requires a multiplexer, TD-1013/ASM-440, which weighs 7.8 pounds, to route the appropriate radar power, VSWR, and aircraft line voltage signals to the DVOM. Replacing the DVOM with newer equipment would provide the Navy with an opportunity to reduce the aircraft's weight.

Finally, changes in E-2C standard operating procedures provide another reason to replace the DVOM. In the past, the E-2B and E-2C aircraft operated with an enlisted flight technician, whose duties included in-flight troubleshooting of the weapon system. The flight technician would use the DVOM to read out test point voltages to isolate system failures. However, the E-2C no longer operates with flight technicians. Instead, the weapon system is operated by three Naval Flight Officers (NFOs), who have no training in system testing and troubleshooting. Therefore, the DVOM no longer has a practical use beyond the display of radar power, VSWR, and aircraft line voltage.

Northrop Grumman, the E-2C prime contractor, proposed an ECP to replace the DVOM with a Power Monitor Panel consisting of three analog meters which display radar power, VSWR, and aircraft line voltage. The ECP had considerable merit in that it would replace the DVOM with a unit providing increased reliability and maintainability, reduced weight, and improved logistics supportability. However, the ECP, with a total cost of several million dollars, was considered cost-prohibitive by the E-2C Program Manager. Therefore, an alternative solution was required.

### **IDENTIFICATION OF ALTERNATE APPROACH**

The Naval Inventory Control Point (NAVICP), formerly known as the Aviation Supply Office (ASO), has programs in place such as Best Overall Support Solutions (BOSS II) which provide funding to organizations that have developed cost-effective solutions to supportability problems. The Naval Air Warfare Center-Aircraft Division (NAWC-AD), Patuxent River, MD, Logistics Competency (3.2.2), submitted a BOSS II proposal to NAVICP for replacement of the DVOM with a Panel Indicator (P/I). The P/I design was similar to that of the Power Monitor Panel proposed by Northrop Grumman; however, the total cost of the P/I program was significantly less. The estimated cost for the entire P/I program, including P/I design, manufacturing, flight testing, qualification testing, technical directive development, technical publication changes, ECP preparation, and retrofit kit installation, was \$400,000, as opposed to several million dollars for the prime contractor-proposed ECP.

NAVICP reviewed the BOSS II proposal for the P/I, and the NAVICP E-2/C-2 Weapons Management Branch technical section determined that the P/I proposal had merit. The proposal

was then presented to the BOSS II Pre-Investment Board. Based on the initial investment of \$400,000, a lead time of five months for first delivery, a total retrofit completion time of two years, and a 4:1 return on investment ratio, the P/I proposal was approved<sup>1</sup>.

## **PANEL INDICATOR DESIGN**

The P/I, which was designed by NAWC-AD 3.2.2 personnel, consists of two analog DC voltmeters and one analog AC voltmeter designed to the requirements of MIL-M-10304, with integral lighting, front and rear EMI-shielded enclosures, an internal wiring harness, and attaching hardware. The P/I meters were procured from Phaostron Instrument and Electronic Company. The P/I front panels were manufactured by a local machine shop. The P/I rear enclosures were procured from Zero Enclosures Incorporated. Final assembly of the P/I was accomplished by a local support contractor. Drawings for the P/I were developed by the NAWC-AD Range Directorate Mechanical Design and Fabrication Section and by Phaostron.

The P/I is constructed from 6061-T6 aluminum with dimensions of 11.5"W, 5.5"H, and 3.0"D. It is installed on dzus rails in the same location as the DVOM. The P/I weighs 2.8 pounds, which results in a significant weight reduction over the DVOM. Not only is the DVOM removed, but the TD-1013/ASM-440 Multiplexer, which weighs 7.8 pounds, is also no longer needed, and the nose ballast required to maintain the current aircraft center of gravity is reduced by one pound. The incorporation of the P/I therefore resulted in a net aircraft weight reduction of 33.9 pounds.

In addition to the P/I hardware, aircraft wiring harnesses were required to interface the P/I with the radar and aircraft AC power systems. The wiring harnesses consist of two RG-180 coaxial cables to route radar power and VSWR to the P/I, one shielded wire from the preflight circuit breaker panel to route the aircraft line voltage to the P/I, and one 22-gauge wire from the Radar Operator's terminal board to the P/I to provide the 5 volts AC required for P/I internal lighting. The wiring harnesses were manufactured locally by NAWC-AD personnel. The local manufacture of many P/I components resulted in significant savings to the Navy when compared to typical military avionics manufacturers. In addition, the local manufacture also served to invest government funds in local community businesses, and gave the businesses the opportunity to diversify their product lines.

When the P/I design was completed, a request for nomenclature (DD Form 61) was prepared by 3.2.2 personnel and forwarded to the appropriate DoD Control Point. The P/I was assigned the nomenclature Panel, Indicator, ID-2531/A.

## **PANEL INDICATOR INSTALLATION**

In December 1994, a prototype P/I was assembled at NAWC-AD Patuxent River for installation into a NAWC-AD E-2C aircraft. The prototype was used to determine installation requirements, to conduct flight and ground testing, and to perform a human factors evaluation. The prototype installation commenced on 27 December 1995 and was performed by prime contractor field service personnel assisted by 3.2.2 personnel. The prototype installation was completed on 29 December 1995. During the prototype installation, detailed installation steps

were documented, including weapon replaceable assemblies, panels, and covers requiring removal, as well as consumable parts requirements, to assist in the development of the P/I retrofit technical directive. In addition, NAWC-AD quality assurance personnel and wiring inspectors were present to inspect the prototype P/I installation and ensure that it was safe for flight.

## **GROUND AND FLIGHT TESTING**

After the prototype installation was inspected and determined to be safe for flight, P/I ground tests were conducted. These tests included a functional test to determine if the meters properly displayed radar power, VSWR, and aircraft line voltage, and an Electromagnetic Compatibility (EMC) safety of flight test. During the initial ground tests, 3.2.2 personnel noted that the meters used to display radar power and VSWR were incorrectly scaled. The radar power meter used in the P/I is a 0 to 2 VDC meter scaled from 0 to 1.5 megawatts (MW). The signal used to drive the P/I radar power meter is a positive DC signal proportional to the radar power in MW (i.e., 1.0 MW = 1.0 VDC). Therefore, since the P/I radar power meter was a 0 to 2 VDC meter scaled from 0 to 1.5 MW, the P/I radar power meter read 75% of the actual radar power in MW. Likewise, the VSWR signal is a positive DC signal proportional to the radar VSWR ranging from 1.0 to 1.8 VDC (i.e., 1.0 VDC = 1.0:1 VSWR). The P/I VSWR meter is a 0 to 2 VDC meter scaled from 1.0: to 1.8:1; therefore, the P/I VSWR meter also provided an incorrect reading. The meter manufacturer was notified of the incorrect meter readings, and they implemented the necessary corrective actions in the P/I radar power and VSWR meters.

After completion of the initial ground tests and EMC safety of flight test, P/I flight testing began. In order to keep program costs to a minimum, there were no dedicated P/I test flights. Instead, the P/I performance was evaluated during scheduled NAWC-AD test flights for other projects. Flight testing commenced on 2 January 1995 and was completed on 30 September 1995. During the P/I evaluation, the test aircraft completed 44 flights accumulating 109.8 flight-hours. No P/I failures occurred during the flight testing. Therefore, the Mean Flight Hours Between Failures (MFHBF) for the P/I was indeterminate, since MFHBF is computed by dividing the total number of aircraft flight-hours by the total number of failures. However, 3.2.2 personnel developed a reliability prediction for the P/I in accordance with the parts count method of MIL-HDBK-217F<sup>2</sup>, which indicated a predicted MTBF of 6,515.5 hours.

Likewise, since no P/I failures occurred during the evaluation, the Mean Time To Repair could not be determined. However, the P/I was removed and replaced several times during the evaluation by project personnel. In each case, removal and replacement took less than 3 minutes. In addition, a removal and replacement prediction was performed for the P/I using MIL-HDBK-472B, Appendix A, Table A-V-I<sup>3</sup>. The predicted removal and replacement time for the P/I is 2.0 minutes.

In a further attempt to keep program costs to a minimum, the P/I EMC ground and flight testing was accomplished concurrently with the E-2C Engine Junction Box Modification and Oil Pressure Indication intrasystem and intersystem EMC compatibility evaluation. No meter fluctuations or anomalies were noted during intrasystem and intersystem EMC testing. The P/I was proven to be electromagnetically compatible with the E-2C weapon system.



## QUALIFICATION TESTING

Environmental qualification testing was conducted from 17-20 July 1995. The P/I meters were subjected to a resonance survey using sinusoidal vibration to determine if the meters had any resonant frequencies that corresponded to the E-2C propeller frequency or its harmonics. Testing revealed that the meters had no resonant frequencies within 10% of the E-2C propeller frequency or its harmonics.

Crash safety shock testing was conducted using a 40g shock pulse. The meters did not break apart under the shock. However, the meters were not installed in the panel assembly during the crash safety test. Therefore, it was not determined what effect the 40g shock pulse has on the entire P/I. However, the P/I uses the same mounting hardware as the DVOM, is installed in the same aircraft location as the DVOM, and weighs approximately 2.8 lbs as compared to 29 lbs for the DVOM. Therefore, the P/I should not present any hazard to operators in the event of an aircraft crash.

Explosive decompression testing was conducted from 18-20 July 1995. The meters were placed in a cylinder, which was then placed in an environmental chamber. The first test point was rapid decompression from 5,000 feet altitude to 35,000 ft. altitude. Rapid decompression was successfully achieved on the second attempt and pressure stabilization was reached in 4 milliseconds (ms). Four tests were performed at 55,000 feet. On the fourth try, the 55,000 feet rapid decompression was achieved and pressure stabilization was reached in 4 ms.

The meters were removed from the chamber upon completion of the testing and were inspected. No damage was noted nor was any part or fragment separation evident. The meter calibration was within 1% of specification and the meter lighting met specification requirements.

## **HUMAN FACTORS EVALUATION**

The initial P/I installation used meters with a white background, black legends, and red lighting. NAWC-AD NFOs agreed that the configuration was too bright when compared to other equipment in the CIC environment. Additional P/I lighting and background combinations were evaluated by NAWC-AD NFOs. These combinations included white background with black legends and white lighting, black background with white legends and red lighting, and black background with white legends and white lighting. Within the color combinations were varying light intensities (i.e., one light bulb or two light bulbs). Based on recommendations made by NAWC-AD NFOs, the black background with white legends and two white light bulbs was selected as the final configuration.

## **TECHNICAL PUBLICATIONS**

Quite often, new or modified systems and equipment reach the fleet prior to the required technical publications. This places an unnecessary burden on fleet maintenance personnel, who are required to use blue-line publications or manufacturer's source data to test, troubleshoot, and repair the equipment, as well as to order required replacement parts. One of the primary goals in

this effort was to have the required technical publication changes available to the fleet at the same time the retrofit installations were accomplished.

Complete P/I technical publication change page packages were developed for the E-2C avionics theory of operation, removal and replacement, testing and troubleshooting, and illustrated parts breakdown technical manuals. All change packages were developed by the 3.2.2 technical publications section and included both graphics and text. Wiring diagrams and Level IIC technical manuals were not provided, since production of these manuals was beyond the capability of the 3.2.2 technical publications section. These publications are being developed by the E-2C prime contractor.

## **SPARE PARTS**

A total of ten spare P/Is were manufactured to support the P/I program. Based on the predicted reliability of the P/I, additional spares requirements are not anticipated. A three-year warranty was negotiated with the meter manufacturer for repair of the P/I and replacement of failed parts. A two-level maintenance concept (organizational to special intermediate level) was established for the P/I. At the conclusion of the warranty period, failed P/Is will be returned to NAWC-AD 3.2.2, which will serve as the specialized intermediate maintenance activity, for repair and replacement of failed parts. Because of the high reliability of the P/I and the warranty agreement with the meter manufacturer, spare parts provisioning was not required.

## **SUPPORT EQUIPMENT**

The design of the P/I is such that no peculiar support equipment is required for testing, troubleshooting, removal, or replacement at the organizational maintenance level. Testing and troubleshooting the P/I requires at most a multimeter to isolate wiring failures. The P/I is removed and replaced using only a flat blade screwdriver. Furthermore, the AN/ASM-421 DVOM test bench, which is used at Aircraft Intermediate Maintenance Departments (AIMDs) both ashore and afloat, is no longer needed. The AN/ASM-421 occupies 8.66 ft<sup>3</sup>, weighs 75.06 lbs., and costs \$31,820. The removal of the AN/ASM-421 not only saves the Navy money, but also frees up space on the ship's AIMDs, which is at a premium.

## **ECP DEVELOPMENT**

The P/I ECP development began on 1 March 1995. The ECP was prepared in accordance with MIL-STD-973<sup>4</sup>. The ECP was submitted to the Naval Air Systems Command on 29 March 1995 and was approved on 29 June 1995. The ECP went through the NAVAIRSYSCOM Change Control Board without the need for revisions or additional information. The three-month turnaround time between ECP submittal and ECP approval is significantly less than the average time required for prime contractor ECP approval, which averages approximately six months, assuming no revisions are required. If revisions were required, which is often the case, the time to incorporate the revisions and resubmit the ECP could possibly double the ECP turnaround time from six months to one year.

## TECHNICAL DIRECTIVE DEVELOPMENT

Development of the P/I technical directive began with the initial prototype installation at NAWC-AD. A preliminary list of consumable parts requirements, such as wiring, coaxial cable, connector plugs, adel clamps, and spot tie, was prepared during the installation. This list was preliminary due to the unique configuration of the NAWC-AD aircraft, which contained unique project equipment and wiring. Therefore, the actual requirements for consumable items such as adel clamps were different in fleet aircraft. In addition, due to different configurations of fleet aircraft, consumable item requirements varied between fleet aircraft. The potential difference between aircraft was noted in the technical directive. Also, a list of panels, covers, and weapon replaceable assemblies (WRAs) requiring removal was generated, as was a list of technical publications containing removal and replacement procedures for all panels, covers, and WRAs requiring removal.

The technical directive was finalized by 3.2.2 personnel using a stricken E-2C aircraft at NAS Norfolk. The stricken aircraft allowed 3.2.2 personnel the opportunity to double-check the panel, cover, and WRA removal requirements, to make detailed measurements of wiring runs, and to document the step-by-step procedures required to complete the P/I retrofit installation. The P/I technical directive was completed on 28 June 1995 and was approved by NAVAIRSYSCOM on 31 August 1995. The technical directive was verified by E-2C squadron VAW-122 at NAS Norfolk on 31 July 1995 using E-2C aircraft Bureau Number 160008.

## **RETROFIT INSTALLATIONS**

The P/I retrofit installations began on 5 September 1995 at VAW-120, NAS Norfolk. The initial installations were accomplished by 3.2.2 personnel in conjunction with squadron maintenance personnel and prime contractor field service personnel. After squadron personnel and prime contractor field service personnel were familiarized with the detailed installation procedures, they began to perform the retrofit installations in the remaining fleet E-2C aircraft. East Coast squadron retrofits are being accomplished by prime contractor field service personnel, while West Coast squadron retrofits are being performed by squadron maintenance personnel. At this point, approximately 63% of the retrofit installations have been completed. It is anticipated that all retrofit installations will be completed by September 1996, which is one year ahead of the original estimated completion date.

## **TRAINING**

Retrofit installations will be accomplished in calendar year 1996 for five trainers. This includes two E-2C tactics trainers at NAS Norfolk; one integrated systems maintenance trainer at NAS Miramar, San Diego, CA; one integrated systems maintenance trainer at the Naval Aviation Depot, North Island, CA; and one tactics trainer at the prime contractor's facilities.

The NAVAIRSYSCOM Program Manager for training (PMA-205) is developing the new lesson plans that reflect the replacement of the DVOM with the P/I. The lesson plan changes are being generated using the P/I technical directive and the technical publications changes developed by 3.2.2 personnel. The impact of the P/I installation on fleet maintenance training requirements is

minimal. In fact, replacement of the DVOM with the P/I will lessen maintenance training requirements because of the simplicity of the P/I design and operation as compared to the DVOM.

## CONCLUSIONS

The P/I program has proven to be a complete success. Field use has established the P/I as a reliable, maintainable, and supportable replacement for the DVOM. Since the first installation in September 1995, only one P/I failure has occurred, which was a maintenance-induced failure involving an improperly crimped wire. Not only has the P/I program corrected a long-standing fleet deficiency, it will also support the production line as the E-2C aircraft goes back into production. Foreign Military Sales customers have recently expressed interest in the P/I as a replacement for the DVOM in their aircraft.

The greatest benefit provided to the Navy by the P/I program was the savings in both cost and time. The P/I program as executed by the NAWC-AD saved the Navy millions of dollars and was completed years sooner in comparison to the estimated time and schedule of the prime contractor's proposed ECP. In an era of shrinking defense budgets, programs such as the P/I, using non-traditional approaches offered by organizations such as NAVICP, will become more prevalent as the DoD looks for new, creative approaches to resolving fleet logistics shortfalls. It is strongly recommended that DoD organizations with similar logistics problems investigate the use of programs such as BOSS II, which can provide timely, cost-effective solutions.

## REFERENCES

1. Aviation Supply Office letter 035B.1 J0216, "Acceptance Action on Best Overall Support Solutions (BOSS II) Suggestion #94-1145, E-2 Digital Volt Ohmmeter (DVOM)," 10 August 1994.
2. MIL-HDBK-217F Notice 1, "Reliability Prediction of Electronic Equipment," 10 July 1992.
3. MIL-HDBK-472, "Maintainability Prediction," 12 January 1984.
4. MIL-STD-973 Interim Notice 2, "Configuration Management," 24 November 1993.